

Comparison of Titanium Cold Spray Coatings



U.S. Army Research, Development and Engineering Command

Brian M. Gabriel
Matthew D. Trexler
Victor K. Champagne
US Army Research Laboratory

Aaron Nardi
United Technologies Research Center



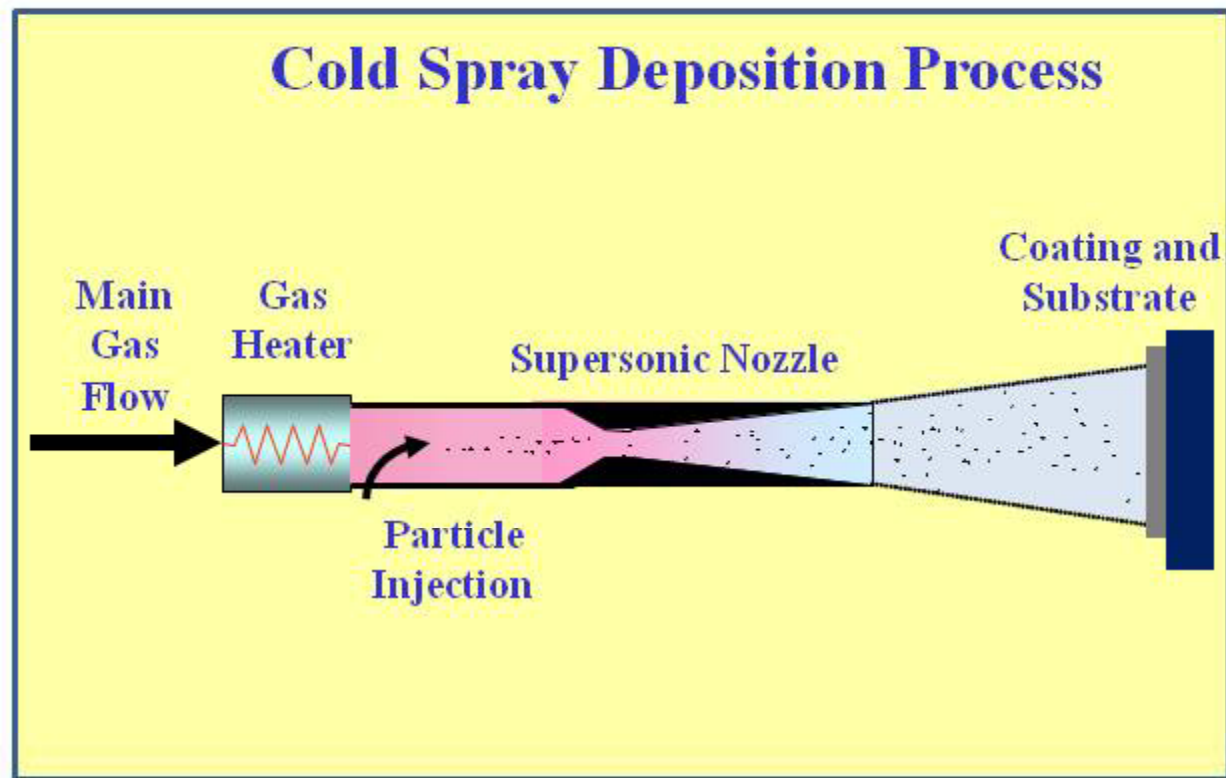
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

ITSC 2012
Houston Texas

24 May 2012



Unique solid-state deposition process which utilizes high velocity particles impinging upon a substrate to build up material



- Feed stock typically ranges from 1 to 50 μm
- Particle ductility is crucial
- Gas temperature range from R.T. to 800° C
- No melting of particles
- Negligible oxidation
- No decomposition or phase changes of deposited particles or substrate



High Pressure Cold Spray



Operating Parameter	Value
Gas Pressure	250 – 550 psi
Gas Temperature	300 - 1000 Degree C
Gas Flow	50 - 200 SCFM
Powder Flow	10 – 50 gram/minute
Particle Exit Velocity	700 - 2000 meter/second



ARL Center for Cold Spray



- World Class Research and Development Facility Recognized Internationally
- ARL Center for Cold Spray est. 2000 (8 dedicated employees, 14 CS systems)

The direct link is: www.arl.army.mil/www/default.htm The link from the homepage is: [Doing Business with ARL | Center for Cold Spray](#)

- Working with over 125 companies, as well as DOD, DOE, Foreign Countries
- Aerospace, automotive, petrochemical, medical & electronics applications
- Cold Spray Additive Manufacturing *Hot Isostatic Press (HIP)
- Integrated Diode Laser with Cold Spray (1KW Continuous)
- DPV 2000 Dual Slit Laser Particle Measuring System
- Developed the first Cold Spray Process Specification (MIL-STD-3021, titled “Materials Deposition, Cold Spray”)



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



ARL CS Systems



Applications development not limited to a particular CS system

- Ktech Stationary Systems 1st Commercial Unit in the USA
- CGT 4000's- Multiple
- Plasma Giken- Japanese Higher Pressure to 1000° C
- Inovati Kinetic Metallization System
- ARL High Pressure (500psi) Portable Cold Spray Systems
- Centerline Portable Cold Spray Systems
- Dymet Portable Cold Spray System
- CGT Portable Cold Spray System (300psi)
- Liquid Particle Acceleration (SBIR Phase II)

Thermal Spray Capabilities

- Thermal Arc Spray, Plasma Spray, HVOF, HVAF, D-Gun
- PTA anticipated FY13



from Prototype to the Field



**Fielded SH-60 Seahawk with Cold Spray Mg Repair
Operating Since August, 2009-Australian Navy
ARL/JSF/DSTO Collaboration**



**Three Fielded Blackhawk Medvac Units with Cold Spray Al Repair
Operating Since August, 2009
ARL/AMCOM/Ft. Hood Collaboration**



**Fielded B-1 Bomber with Cold Spray Ti Repair
Operating Since September 2009- Tinker AFB
ARL/Tinker AFB/HF Webster Collaboration**



**Two Expeditionary Fighting Vehicles with Cold Spray Mg Repair
Fielded and Operating Since September, 2008**



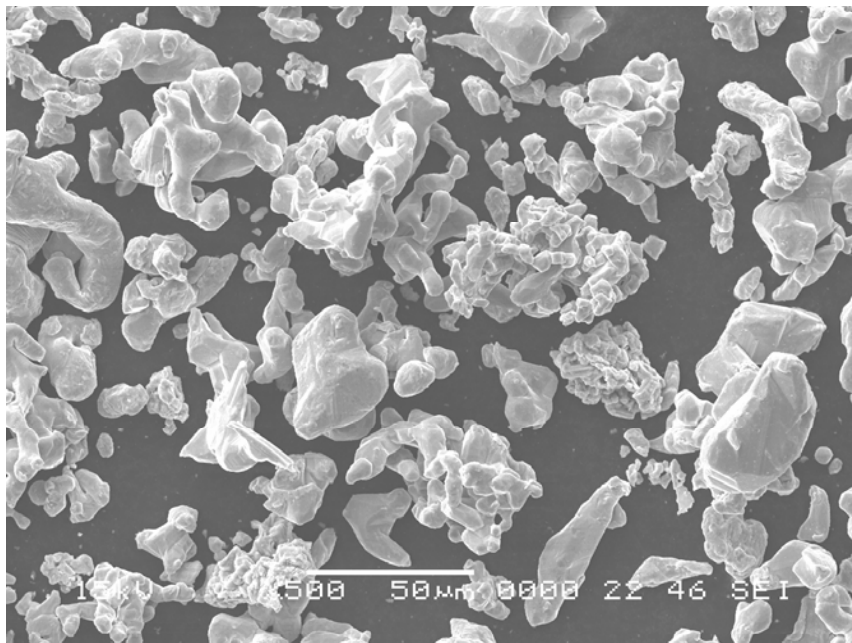
- **Power Transfer Module - PTM**
 - 10 Magnesium Castings
- **Transmission**
 - 13 Magnesium Castings



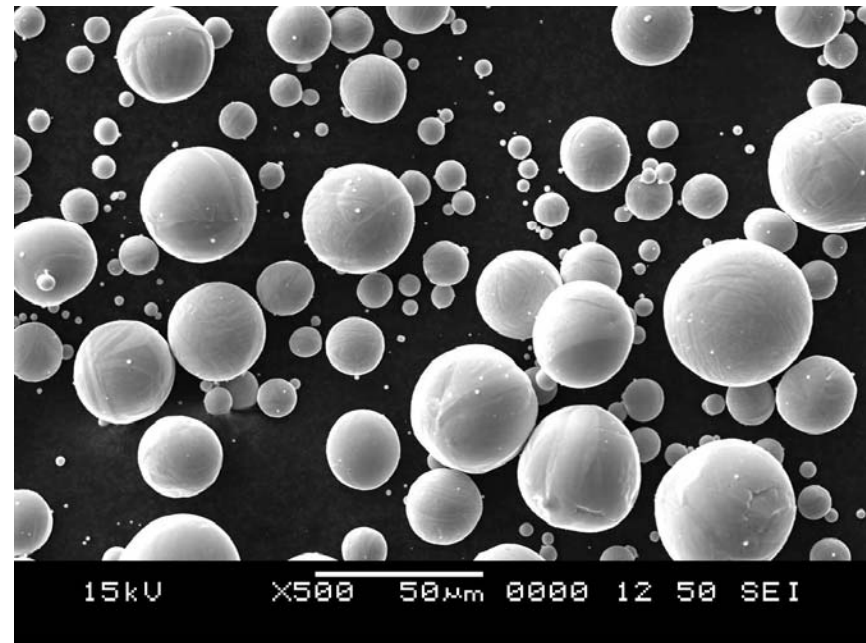
CP Titanium Powders



Difference in Particle Size & Morphology



Accushape CP-Titanium
(Mean Particle Size = 39 μm ,
SD = 27.2)



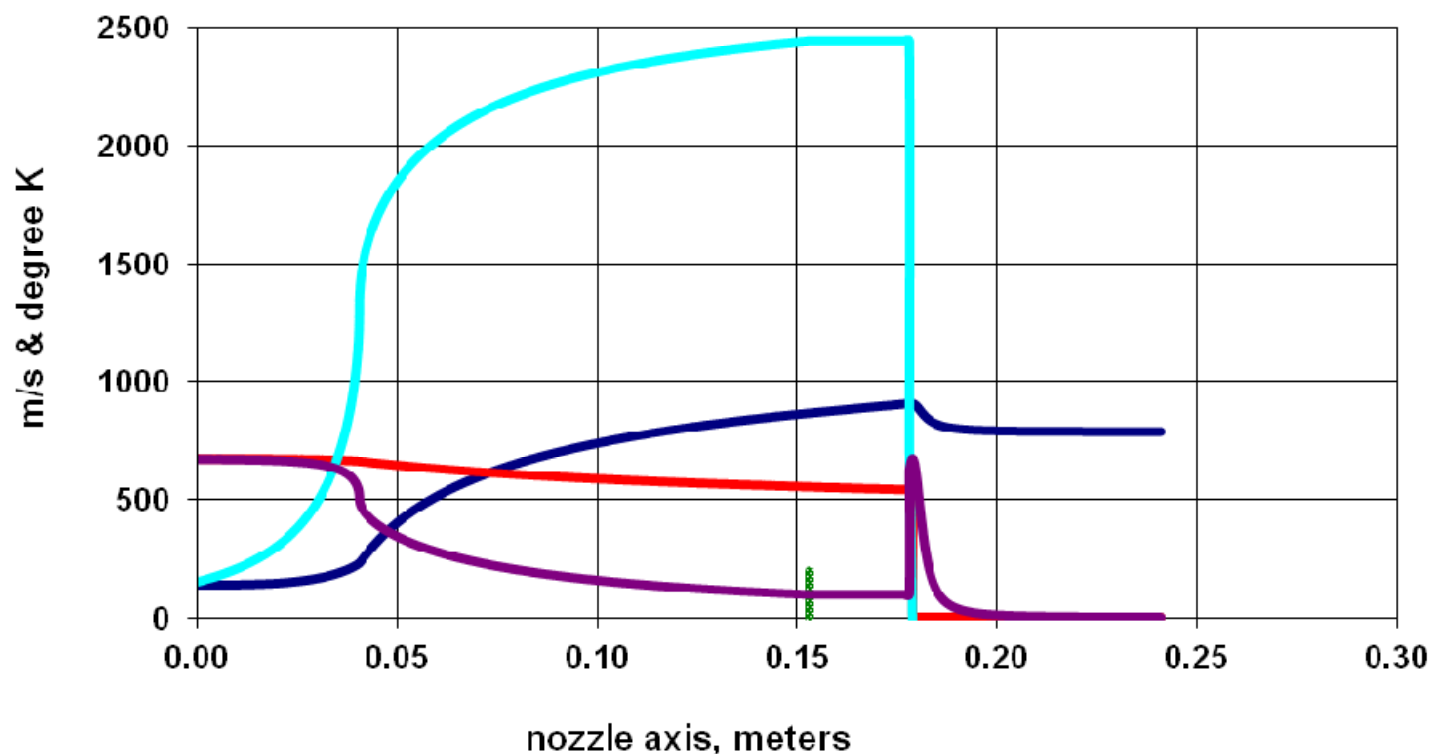
AP&C CP-Titanium
(Mean Particle Size = 12 μm ,
SD= 5.0)



US ARMY
RDECOM

Typical Nozzle Performance

ARL



— particle velocity — particle temp nozzle exit — gas velocity — gas temp

39um powder

Ve, m/s
866

Te, C
280

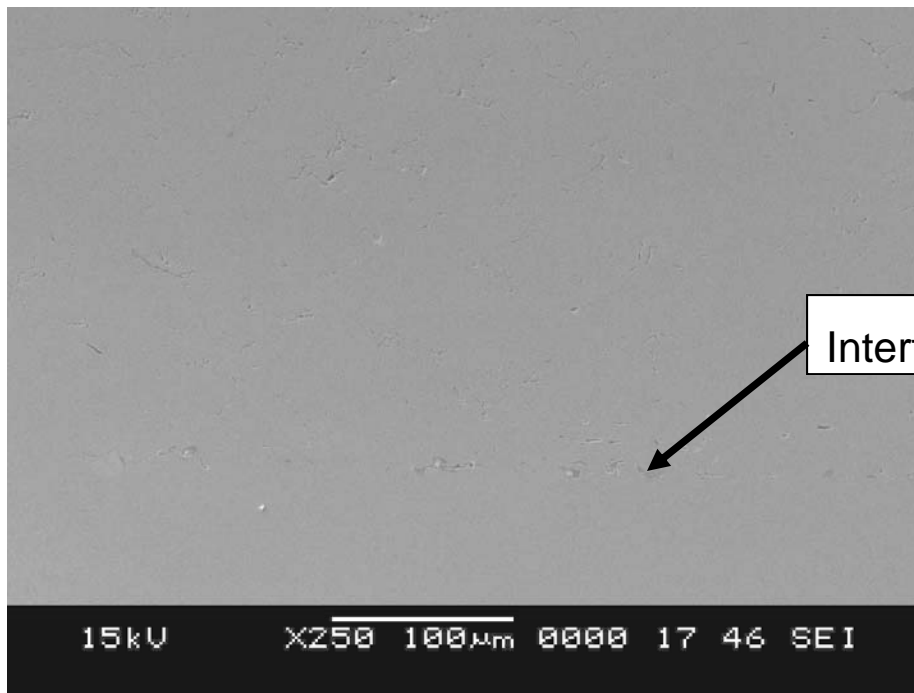
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



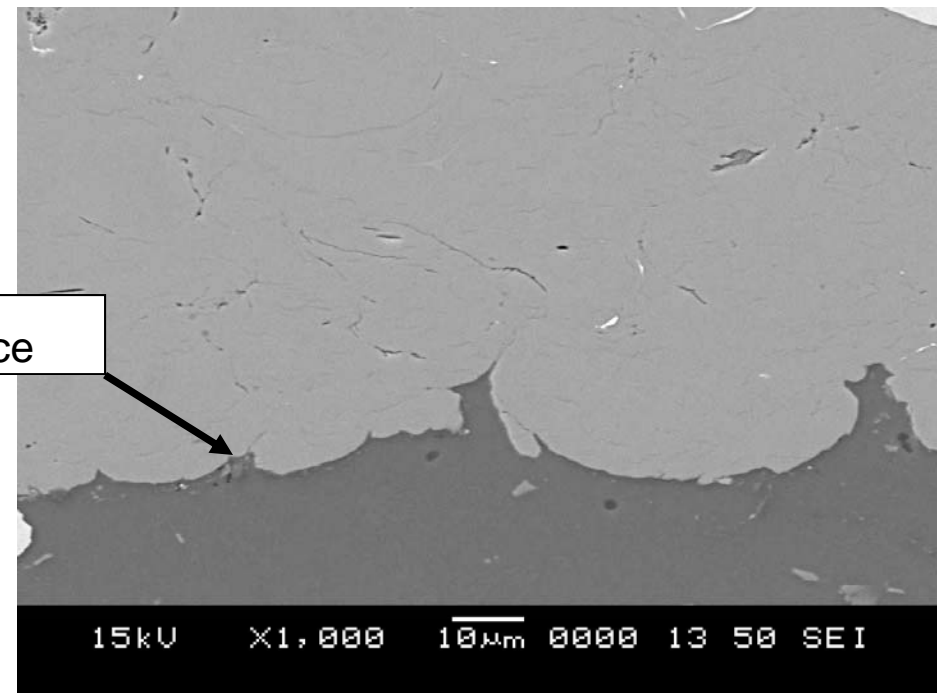
US ARMY
RDECOM

Accushape CP-Titanium Coating

ARL



Interface



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

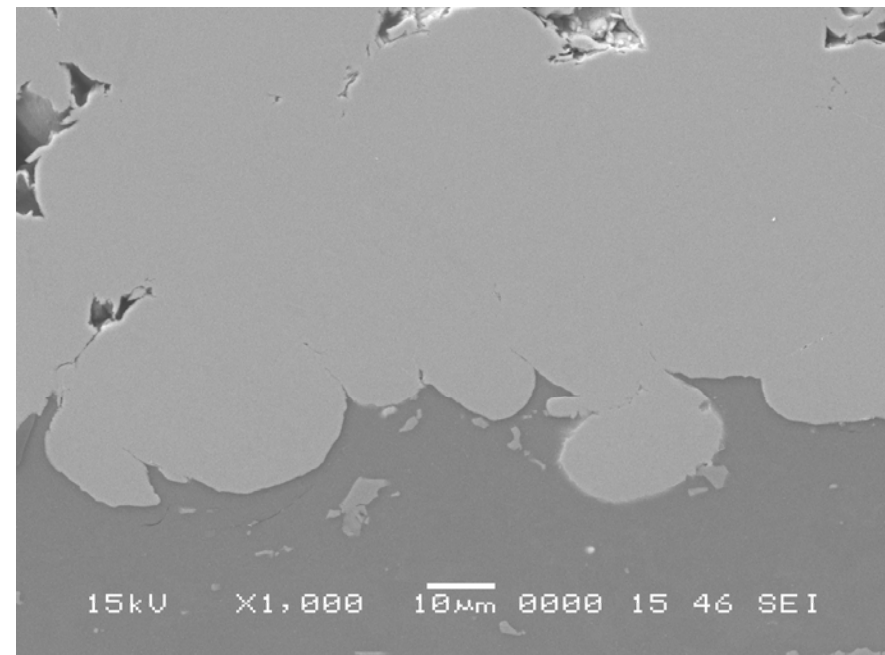
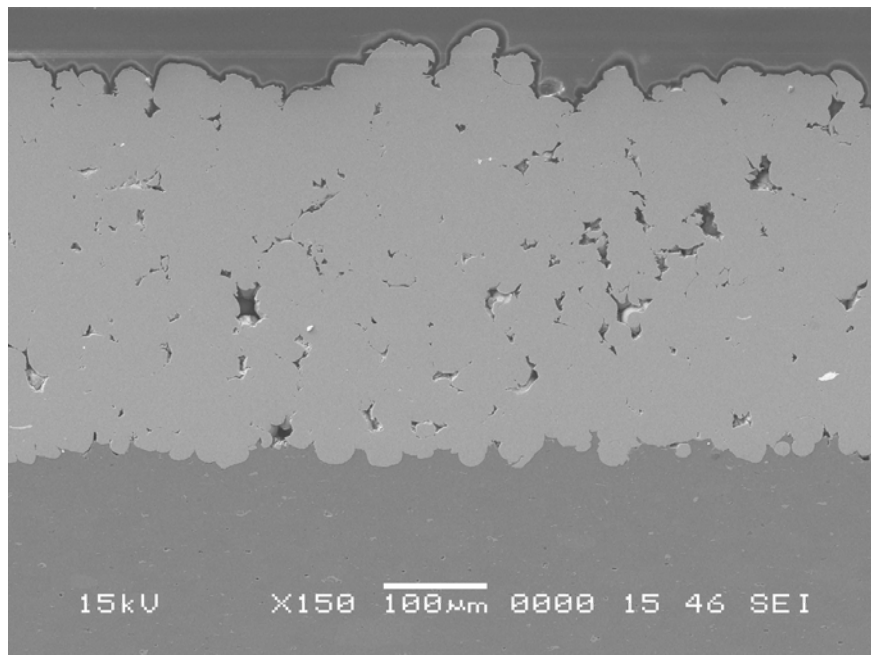


US ARMY

RDECOM

AP&C CP-Titanium Coating

ARL



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



US ARMY

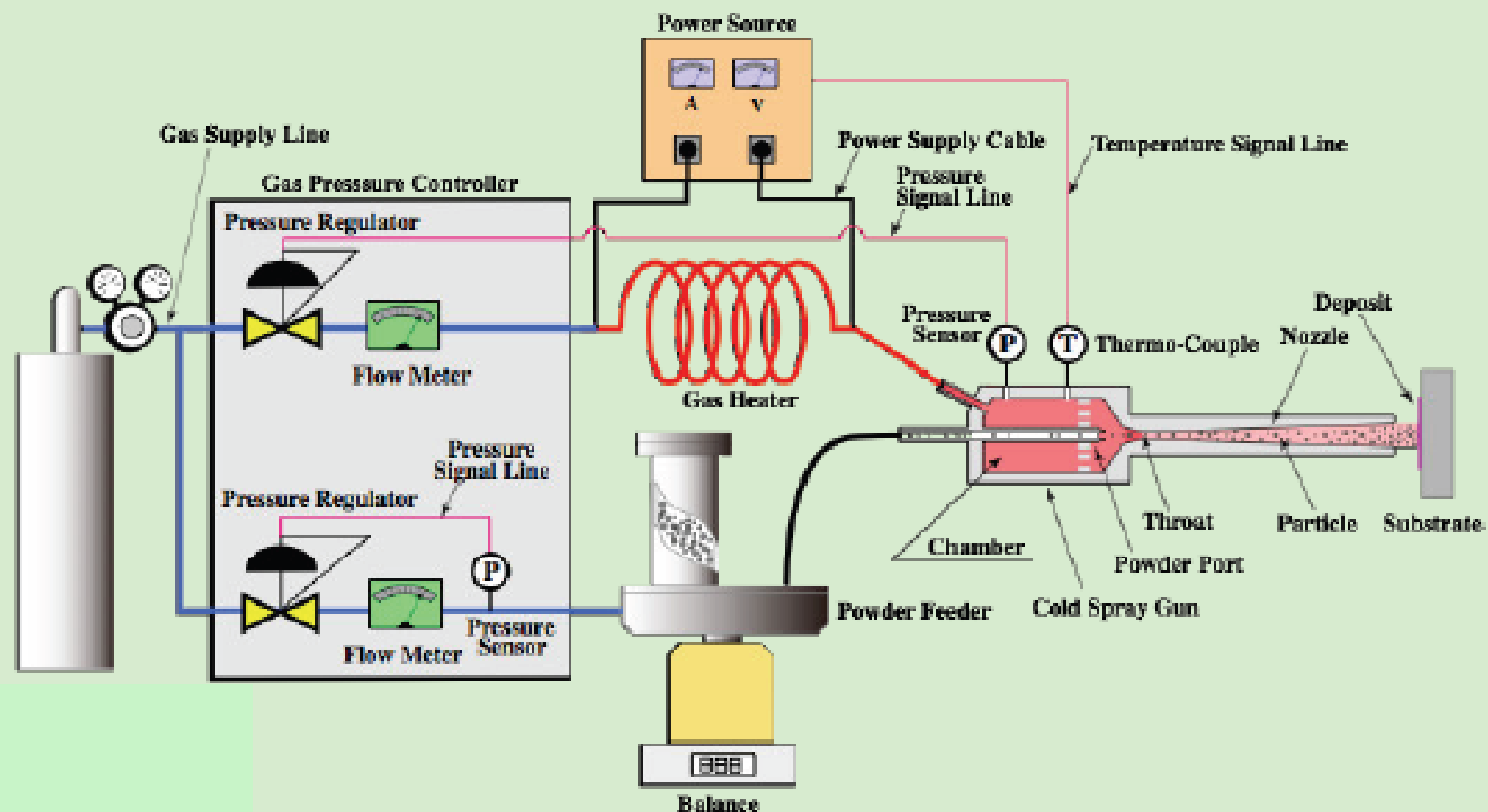
RDECOM

Titanium Coating Adhesion



Powder	Substrate	Adhesion (psi)
Acushape CP-Ti	6061 Aluminum	11233
Acushape CP-Ti	Ti6Al4V	11626
AP&C CP-Ti	6061 Aluminum	9785
AP&C CP-Ti	Ti6Al4V	7166

PCS-305 COLD SPRAY SYSTEM

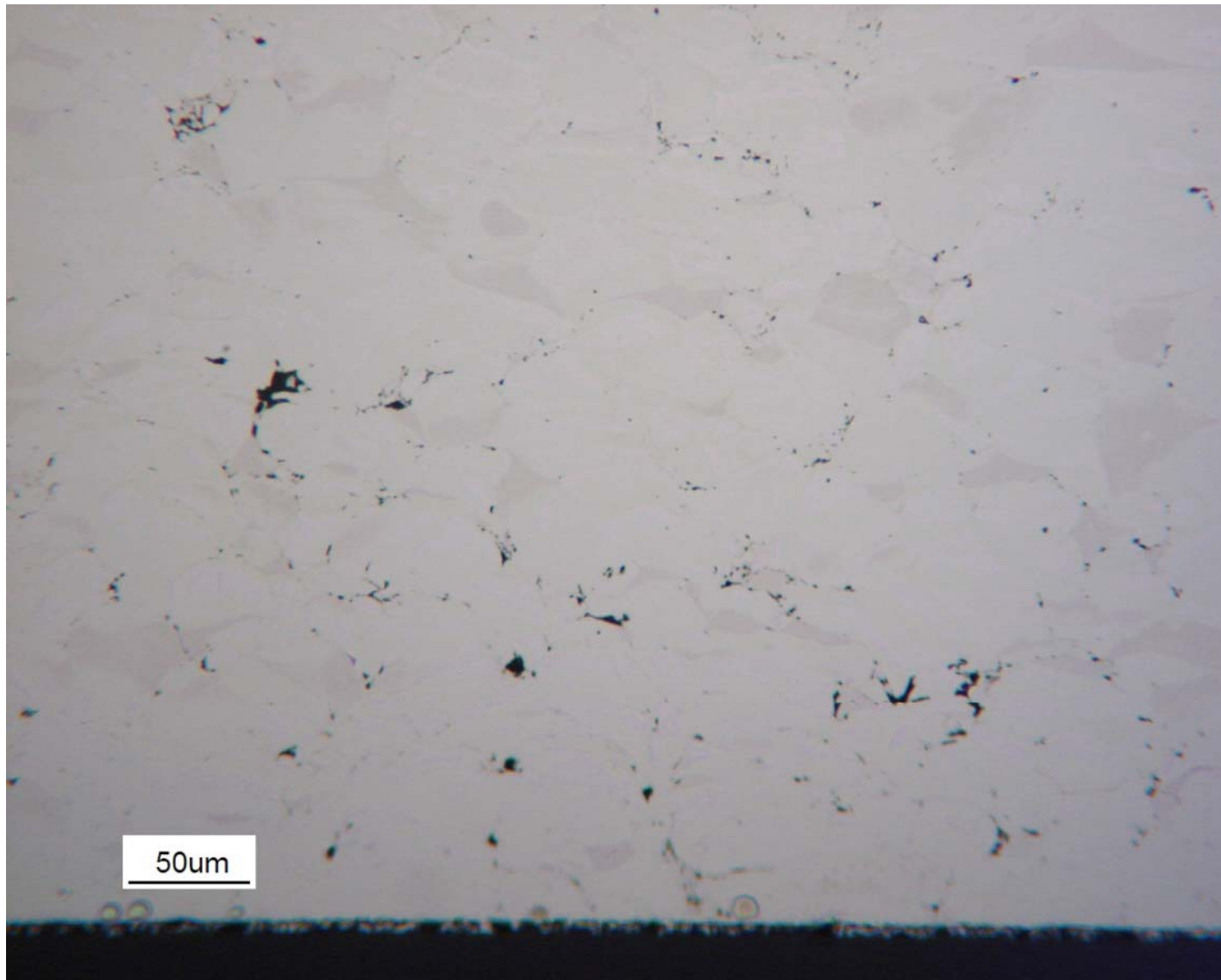




US ARMY
RDECOM

Helium Microstructure Ti-6Al-4V

ARL



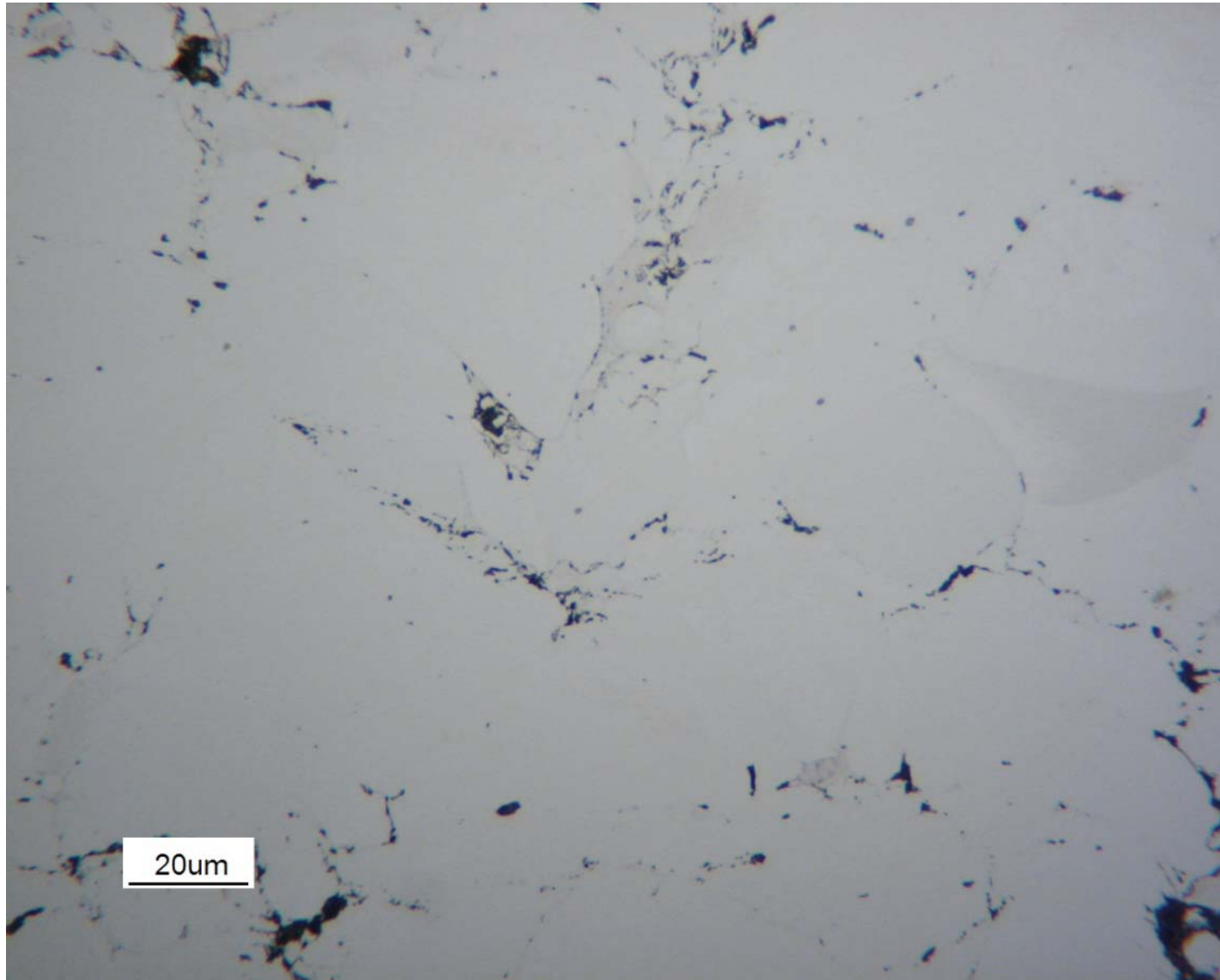
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



US ARMY
RDECOM

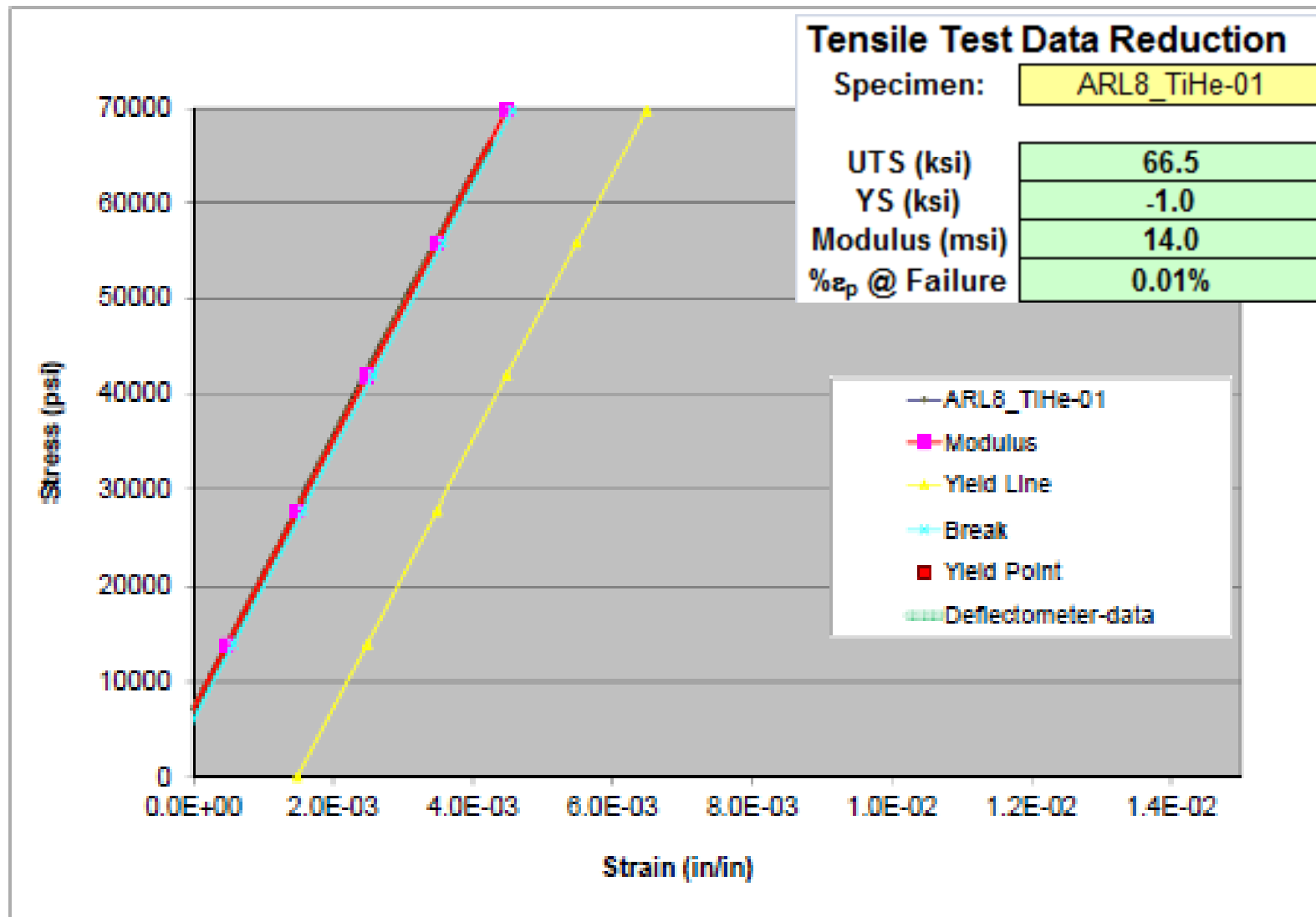
Helium Microstructure Ti-6Al-4V

ARL



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Helium Tensile Properties Ti-6Al-4V

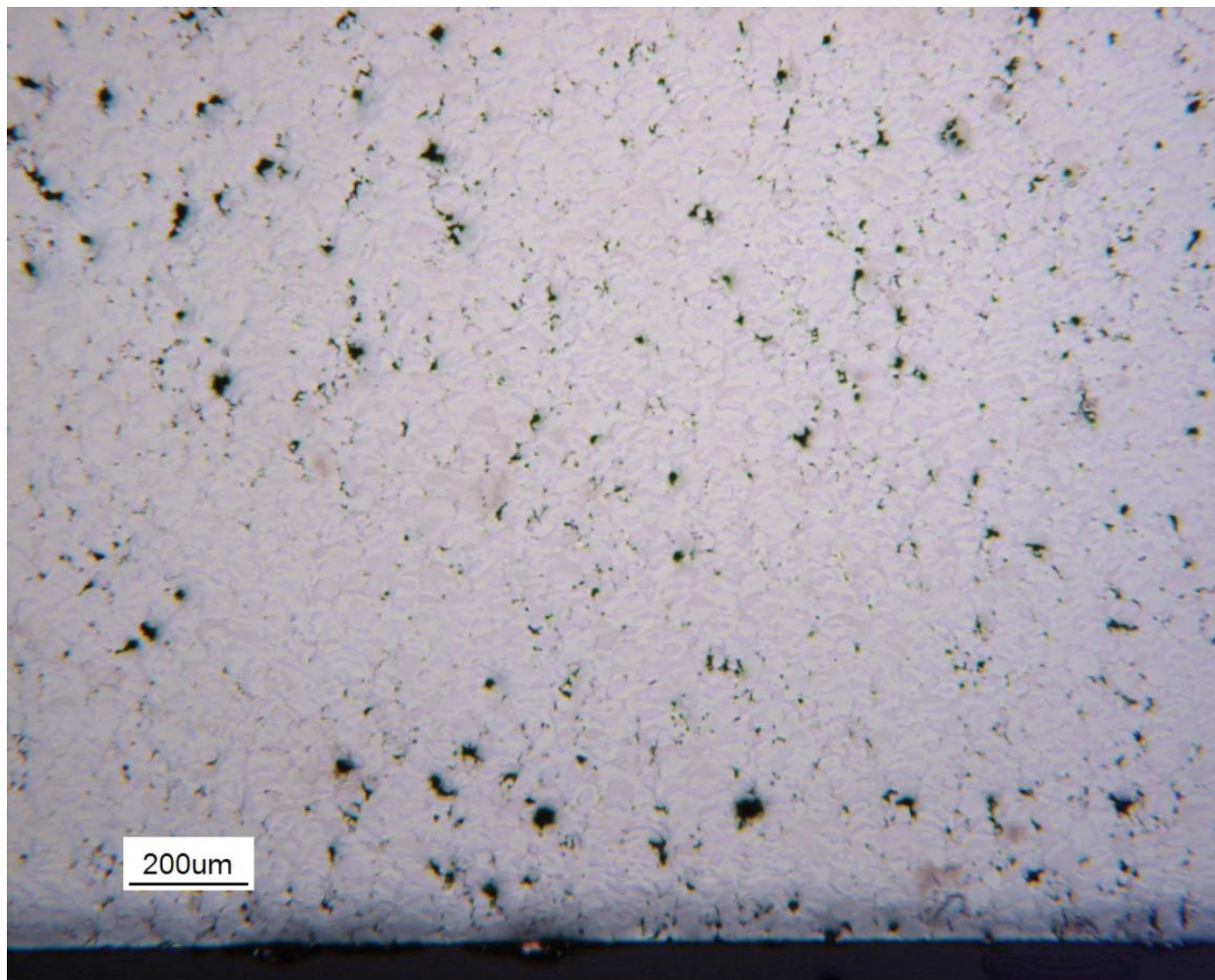




US ARMY
RDECOM

Nitrogen Microstructure Ti-6Al-4V

ARL



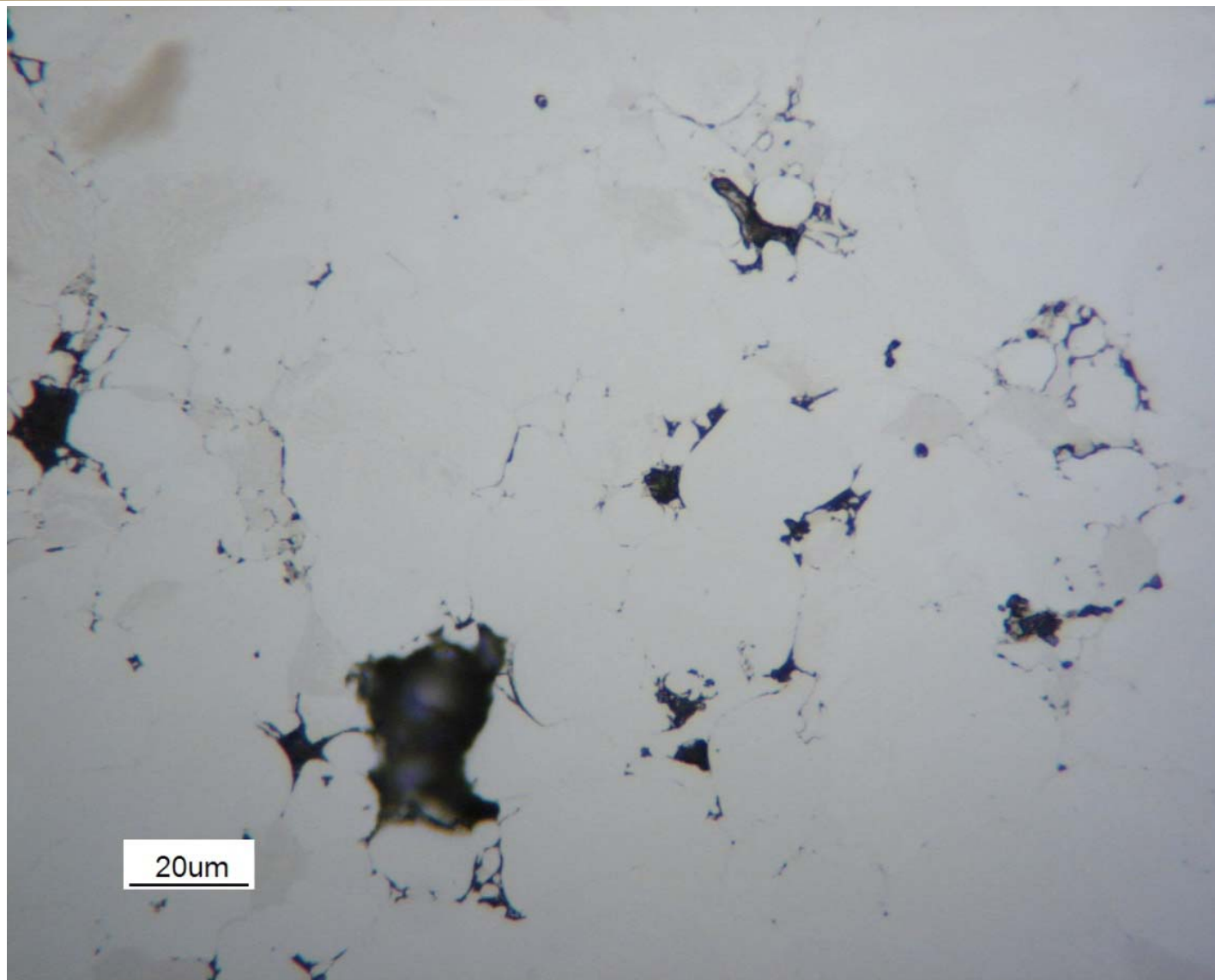
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



US ARMY
RDECOM

Nitrogen Microstructure

ARL



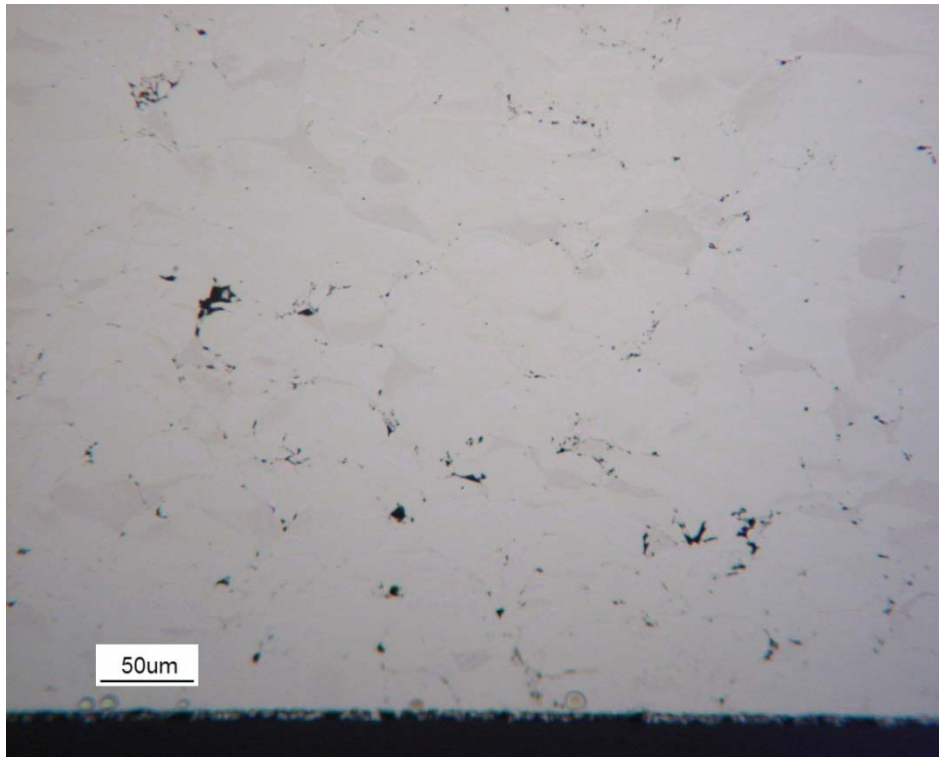
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



US ARMY
RDECOM

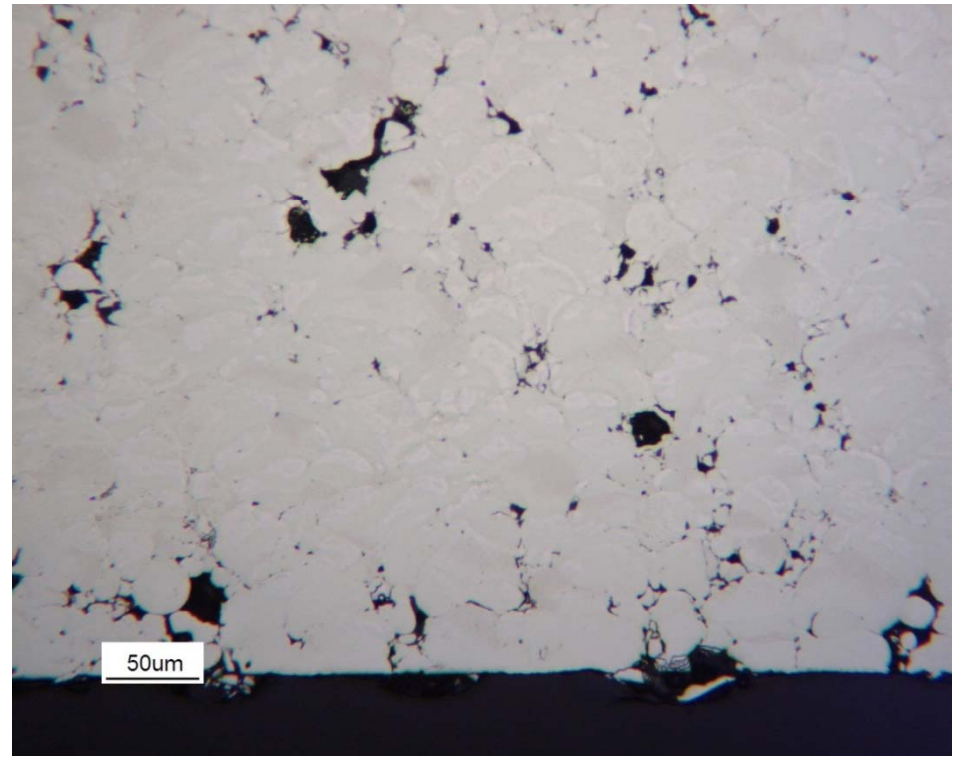
He vs. N₂ Microstructure Ti-6Al-4V

ARL



Helium

Modulus 14.1 msi
Strength 60 ksi



Nitrogen

Modulus ~2 msi
Strength ~10-20 ksi

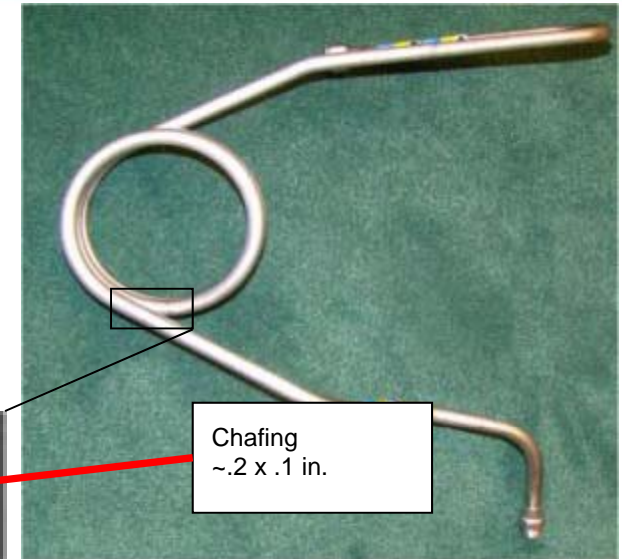
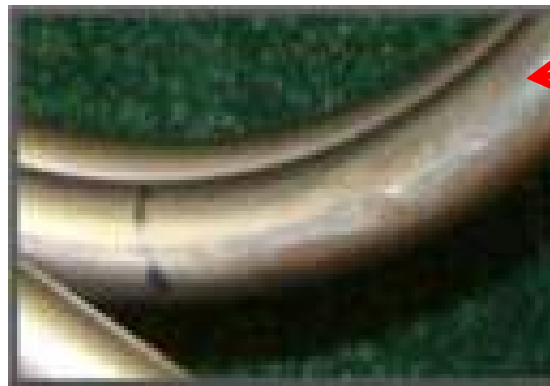
Problem: *Chaffing of hydraulic tubing is a common problem*

Cause: *Vibration or other Abrasive action*

Effect: *Significant cost in maintenance man-hours and operational readiness rates*

Replacement is expensive

Solution: *Cold Spray Repair*





Cold Spray Solution



- ***A technological solution that reduces the frequency of hydraulic tubing chafing would have broad applicability across the DOD and would result in***
 - ***Reduced maintenance man-hours***
 - ***Reduced costs***
 - ***Improved mission capable rates.***

- ***Supersonic Cold Spray is a technology which can be used to apply a metal coating on titanium tubing providing a wear surface in areas of known chafing problems. This preventative measure could be performed during programmed depot maintenance or during the high velocity maintenance process to prevent or reduce occurrences of hydraulic tubing chafing in the field.***



US ARMY
RDECOM

Cold Spraying CP-Ti on Hydraulic Tubing

ARL



Application of Cold Spray to .375" Haynes AMS 4944 (Ti3Al2.5V) Hydraulic Tubing

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Cold Spraying CP-Ti on Hydraulic Tubing



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

- Cold Spray can be used to deposit fairly dense CP-Titanium and Ti-6Al-4V coatings
 - It is difficult to achieve a good quality Ti-6-4 with N₂ using currently available high pressure systems
 - Helium can be used to deposit a reasonable quality Ti-6Al-4V coating
- It is feasible to use Cold Spray as an Additive Manufacturing technology for Titanium alloys
 - Need a decrease in porosity and an increase in ductility (particle to particle bonding)
 - Next step is try a angular Ti-6Al-4V Powder
- Already have identified numerous applications such as the B-1B where these coatings can possibly be implemented